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BEST MANAGEMENT PRACTICES FOR MOSQUITO CONTROL

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Send comments to:

Kathleen Emmett
Water Quality Program
PO Box 47600
Olympia, WA 98504-7600
Telephone 360-407-6478
Fax 360-407-6426
kemm461@ecy.wa.gov

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INRODUCTION

On April 10, 2002, The Washington State Department of Ecology (Ecology) issued a general permit (NPDES Permit No. WAG-992000) covering all mosquito control activities that discharge insecticides directly into surface waters of the state. Under the permit, the use of insecticides for mosquito control in water is allowed when the effects are temporary and confined to a specific location, though locations where insecticides are used may be widespread throughout the State. Applications of insecticides are subject to compliance with Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) labelsmonitoring requirementsand reporting. Permittees must meet a compliance schedule for the preparation and implementation of best management practices (BMPs) that include a hierarchy of preferred integrated pest management options.

Since the issuance of the permit, the focus of mosquito abatement has grown from being primarily a nuisance control issue to a widespread human health concern. The West Nile virus, a mosquito-borne disease that has been steadily spreading westward across the United States since 1999, reached Washington State in the fall of 2002. A raven from Pend Oreille County and a crow from Snohomish County collected as part of a statewide dead bird surveillance effort tested positive for the virus. A horse in Island County and a horse in Whatcom County also tested positive. These are the first detections of West Nile virus in our state. Transmitted by mosquito bites to humans, the virus has proven itself a low risk public health threat. As of November 26, 2002, nearly 4000 human cases of the illness have been reported nationwide to the Center for Disease Control and Prevention, including 214 fatalities. In looking at the progress of the virus as it has spread across the United States, it appears that mosquito control efforts have no effect halting the continued spread of this virus. They can, however, reduce the risk of exposure in some cases.

Due to the human health threat posed by mosquitoes, many local governments and others are now preparing to conduct mosquito control activities, focusing primarily on education and surveillance. Many are also gearing up to respond to disease outbreaks by larviciding and are pursuing permit coverage to perform these activities in surface waters. Since these activities are projected to be wide-spread and often conducted by entities with limited budgets, Ecology has taken the lead on preparing the best management practices (BMPs) required by permit condition S4. These BMPs will be available to any entity that chooses to adopt them. The following BMPs are the result of a collaborative effort among the Departments of Health, Agriculture, Fish and Wildlife and Ecology, King County, Washington State University and several Washington-based mosquito control districts.

MOSQUITO MANAGEMENT ENTITIES

When individual protective efforts are not sufficient, public agencies that are either components of local health departments or are independent districts organized specifically for mosquito control can provide an effective way to manage mosquito infestations on an area-wide basis. In some cases, individuals, communities and other organizations may want to hire private mosquito control applicators for targeted treatments. However, if long-term mosquito management is desirable, establishing a mosquito control district may be the best and most cost-effective alternative.

In Washington, local mosquito control districts are organized under RCW 17.28. Unless a district is formed under RCW 17.28 or a public health emergency is declared, it is unlawful to treat the property of individuals without their permission. This regulation gives districts authority to spray those areas where excessive infestations are occurring, even if property owners do not want their property sprayed. The ability to enter onto private lands for mosquito control requires that a resolution be adopted by a mosquito district. There may be valid safety reasons why a landowner does not allow access to a piece of property. As an alternative, the regulation states that the local mosquito control board may require the landowner to control mosquitoes.

The formation of mosquito control districts can provide a self-taxing, long-term method of mosquito control, but it may take up to two years to form a district. In the short-term, local public health entities may need to take effective abatement measures. Abatement programs can be organized, and abatement treatments performed, on cooperating property owner sites. Effective abatement programs start with a preliminary assessment and the development of an implementation strategy, including public education and outreach, and progressively lead up to organizing treatment responses.

MOSQUITO LIFE CYCLE AND BIOLOGY

There are several species of mosquito that readily attack people, and some species are capable of transmitting microbial organisms that cause human diseases such as malaria and encephalitis. The mosquitoes of major concern in Washington belong to the genera *Culex*, *Culiseta*, *Aedes*, *Ochlerotatus* and *Anopheles*.

Mosquitoes are classified as Insects of the *Diptera* order. They undergo a complete metamorphosis, which involves four stages of development: egg, larva, pupa and adult. The first three stages occur in water, but the adults are active flying insects. The female feeds upon the blood of humans and animals before laying eggs directly on water or on moist substrates likely to become flooded with water.

Eggs later hatch into larvae, the stage they are most vulnerable to control efforts. During the larval stage, they continue to feed and grow in size. Larvae go through four growth stages called instars. Once larvae have developed to the fourth instar, they stop feeding and transform into pupae where internal changes occur and adult mosquitoes take form. This is a resting period. At this point, bacterial larvicides no longer work as a control measure because they require ingestion by the organisms; however, monomolecular surface films and petroleum distillates are effective on pupae. Draining or emptying the water at this point will also kill the pupae, as they are unable to live out of water. After a few hours to a few days in the pupal stage, the adult mosquito emerges from the water surface and seeks shelter in shady, moist areas. Adult mosquitoes must find shelter during the heat to avoid dehydration and are most active from dawn to dusk. After a brief period of rest, the adult female goes in search of a blood meal and the cycle continues. The time frame for this is highly variable, anywhere from one to three weeks, depending on the temperature of the water. The warmer the water, the quicker the development will be. A small amount of water in a container in the sun will produce a batch of adult mosquitoes very quickly.

Mosquito biology can follow two general scenarios. The first involves those species that lay their eggs in masses or rafts on the water's surface. These species, found throughout the U.S., often lay their eggs in natural pools, puddles or man-made water-holding containers. In summer the entire life cycle, from egg to adult, may be completed in a week or less.

The second scenario involves *Aedes* mosquitoes that lay their eggs on moist soil or other substrates periodically flooded with water. After about two days in water, these eggs are ready to hatch, but if not flooded, can withstand drying for months and longer. In inland areas of the U.S. where these mosquitoes breed, heavy rains and flooding can produce millions of mosquitoes in a short time. Similar situations occur along coastal areas with mosquitoes adapted to salt marsh habitats. Some salt marsh mosquitoes are strong fliers that can travel up to 50 miles from the breeding site.

The main concern with the use of authorized insecticides is the long-term adverse impact from efforts to eradicate mosquitoes, especially impacts to non-target organisms. Other species which may be inadvertently killed by a mosquito pesticide (non-target species) include other insects, daphnids (water fleas), flies, copepods, mysid shrimp, and many others. Agents that kill mosquito larvae may also kill these related beneficial species. Many animals such as fish and birds depend on these species for food. Plants depend on mosquitoes and many of these other species for pollination. Effects other than death may also occur in nontarget species from compounds such as methoprene, which is an endocrine disruptor (disrupts glandular secretions of hormones.)

Nontarget species that live in water include some of the most important food items for small fish and the young of larger fish such as salmon. Daphnids and the larvae of insects are particularly important fish foods. This is the reason the United States Environmental Protection Agency (EPA) included daphnids in their manuals for aquatic toxicity testing and insect larvae for sediment toxicity testing. If the populations of these important organisms are reduced in a water body due to mosquito control agents, then small fish there may starve. These small fish would also eat mosquito larvae. Other predators of mosquitoes such as dragonflies and copepods could also be reduced. If there are fewer predators of mosquitoes, the need for pesticides to control them can become greater. It becomes a vicious cycle.

IPM - BASED BEST MANAGEMENT PRACTICES

Current interest in the environmental impacts of mosquito control measures, and increasing problems that have resulted from insecticide resistance, emphasize the need for "integrated" control programs. Integrated Pest Management (IPM) is an ecologically-based strategy that relies heavily on natural mortality factors and seeks out control tactics that are compatible with or disrupt these factors as little as possible. IPM includes the use of pesticides, but only after systematic monitoring of mosquito populations indicates a need. Ideally, an IPM program considers all available control actions, including no action, and evaluates the interaction among various control practices, cultural practices, weather, and habitat structure. This approach thus uses a combination of resource management techniques to control mosquito populations with decisions based on surveillance. Fish and game specialists and natural resources biologists should be involved in planning control measures whenever delicate ecosystems could be harmed by mosquito control practices.

An integrated pest management program for mosquitoes should include all the features of IPM as defined in Washington State law (RCW 17.15.010) and adapted to mosquito management:

1) Minimization of mosquito breeding sites,
2) Monitoring for high mosquito populations and disease,
3) Establishing the targeted density of the population based on health, public safety, economic and aesthetic thresholds,
4) Treating mosquitoes to reduce populations below the targeted threshold using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost effectiveness, and
5) Evaluating the effects and efficacy of pest treatments.

GOALS, LOGISTICS AND ACTION THRESHOLD DETERMINATIONS

The goal of BMP-based mosquito control efforts is to achieve a level of control sufficient to maintaining an acceptable level of risk (exposure to vector and/or nuisance adult mosquitoes) with the least possible adverse impact to the environment.

Success at meeting that goal will depend on several factors. First, securing long-term funding will be necessary, by forming a self-taxing mosquito control district or creating a funded program housed in a government agency. In addition, applications of insecticides to water must be made by individuals licensed by the Washington State Department of Agriculture and permitted by the Department of Ecology’s Water Quality Program. Individuals and organizations conducting mosquito control activities must be licensed and permitted before insecticide activities can commence, a process that takes at least 38 days. Information on WSDA license requirements is online at http://pep.wsu.edu or call WSDA toll-free at (877) 301-4555. Permitting information is available from Ecology's website at www.ecy.wa.gov/programs/wq/pesticides/index.html or call (800) 917-0043.

Appropriate mosquito management strategies vary depending on action threshold determinations (see below), the size and type of area to be treated, the species of mosquito, and the stage of the mosquito life cycle being targeted. Mosquito control programs include source reduction, surveillance, the use of a variety of mosquito control strategies and ongoing evaluation. While education provides individuals the most personal protection, the underlying philosophy of mosquito population control is that the greatest control will occur when the mosquitoes are concentrated, immobile and accessible. This emphasis focuses on habitat management and controlling the immature stages before the mosquitoes emerge as adults. Under these conditions, insecticides are dispersed only where mosquito larvae are present and not indiscriminately, which is why larviciding is much sounder than adulticiding.

Mosquito control agents and/or the sponsors who hire them must set action level thresholds to determine when appropriate area-wide efforts should be triggered. The action level thresholds proposed in this model BMP plan for mosquito control may be adopted, or modified as needed and then adopted, by all mosquito control entities covered under Ecology's permit: Aquatic Mosquito Control National Pollutant Discharge Elimination System Waste Discharge General Permit No. WAG – 992000(Permit). *Entities wanting to set action level thresholds other than those proposed here or those who wish to develop their own BMP/IPM plan must have their individual plans approved by Ecology before they can apply pesticides to surface waters in Washington State.*

BMPS FOR MOSQUITO CONTROL

1. Minimization of mosquito breeding sites and biting opportunities

Risk Assessment: Probability of outbreak in humans: Remote
Action threshold: The presence of mosquitoes (any species) or any suspected presence of mosquitoes in the area of control may trigger minimization efforts in the early spring and summer. The mean development time from egg hatch to pupation takes 5 to 10 days at temperatures near 25º C (77º F) (Pratt and Moore, 1993). However, certain species of eggs can hatch in water as cold as 45º F (Lilja, 2002, p. 24). Minimization actions, therefore, are most effective when taken in the early spring and continued through fall on an as-needed basis.
Rationale: Because mosquito-borne diseases have been positively identified in Washington State, measures to educate people about minimizing mosquito breeding sites and biting opportunities around homes and offices should be adopted. Minimizing breeding sites in the targeted area of control, and personal protection, especially for those with compromised immune systems, are the best defenses against exposure, giving the best protection for the least cost.
DOH Recommended Response: Obtain surveillance and control resources to enable emergency responses. Initiate community outreach and public education programs. Conduct entomologic surveys (inventory and map mosquito populations) and monitor avian mortality, human encephalitis/meningitis, and equine outbreaks (Lilja 2002, p. 16).
Minimum BMP Response: Conduct a set level of minimal education and outreach in the area of control, enlisting assistance from local government (*i.e.* the local environmental health department), if possible. Track reports in the local area for avian mortality, human encephalitis/meningitis, and equine surveillance.

A. Minimization techniques for mosquitoes control around *private homes or offices* primarily involve educating those in the area of control about eliminating mosquito breeding sites, using repellents and protecting domestic animals. The following is a general list of actions that can be taken around private homes and offices. Additional information is available from the federal Centers for Disease Control and Prevention at http://www.cdc.gov/ncidod/dvbid/westnile/index.htm.

- Empty or turn over anything that holds standing water—old tires, buckets, wheelbarrows, plastic covers, and toys.
- Change water in birdbaths, fountains, wading pools and animal troughs weekly.
- Remove all human-made potential sources of stagnant water where mosquitoes might breed.
- Drill holes in the bottoms of containers that are left outdoors.
- Clean and chlorinate swimming pools that are not in use and be aware that mosquitoes can breed in the water that collects on swimming pool covers.
- Aerate ornamental pools and use landscaping to eliminate standing water that collects on your residence; mosquitoes can potentially breed in any stagnant puddle that lasts more than 4 days.
- Recycle unused containers—bottles, cans, and buckets that may collect water.
- Make sure roof gutters drain properly, and clean clogged gutters in the spring and fall.
- Fix leaky outdoor faucets and sprinklers.
- Keep all ornamental shrubs and bushes trimmed and pruned to open them up to light and air flow. This will not only give mosquitoes fewer places to hide, but will promote growth and vigor in the plants.
- Stock water gardens with mosquito-eating fish recommended by the State Department of Fish and Wildlife (i.e., mud minnow, stickleback, and perch). Tadpoles, dragonfly larvae, diving beetles, back swimmers and front swimmers also prey on mosquito larvae. For more information, contact WDFW's Aquaculture Coordinator, Andy Appleby at (360) 902-2663 or e-mail him at appleaea@dfw.wa.gov.
- Make sure window and door screens are "bug tight." Repair or replace if needed.
- Stay indoors at dawn and dusk when mosquitoes are the most active.
- Wear a long sleeve shirt, long pants, and a hat when going into mosquito-infested areas such as wetlands or woods.
- Use mosquito repellant when necessary, and carefully follow directions on the label.
- To protect your horses and other equines talk to your veterinarian about the West Nile virus vaccine. The vaccine requires two doses three to six weeks apart, and immunity may not be achieved until up to six weeks after the second dose. An annual booster should be given a few weeks to a month prior to the start of the mosquito season in your area.
- Veterinarians should be consulted if you have concerns about your household pets or other animals. Repellents may be used in some instances.
- Thoroughly clean livestock watering troughs weekly.
- Do NOT drain or fill wetlands (see next section). Consult with your local health dept. or mosquito control district about managing mosquitoes in wetlands, swamps and low-lying areas.

B. **Mosquito control in *wide areas* involves educating those in the area of control about reducing mosquito breeding sites, using personal protection and protection techniques for domestic animals. Education may need to be targeted to specific areas such as new construction, drainage and water treatment facilities, residential and light commercial occupants, farms and irrigation districts.**

- Education/information on breeding site minimization and personal protection must be provided to people residing in the area of control (see list above). A significant management strategy for controlling mosquitoes is to enlist residents and businesses in the control of larvae around their homes and offices. Many people unknowingly contribute to mosquito problems by not taking steps to minimize breeding sites and biting opportunities. Federal, state and local health departments often have publications and other materials that explain how people can protect themselves and minimize breeding.
- Education/information must be provided about risks to domestic animals, vaccinations and repellents available as well as minimization techniques specific to the area where domestic animals may reside. Direct people to their veterinarian for more information.
- As new facilities are being designed, consideration should be given to reducing mosquito habitat as much as possible.
- When considering a drainage or water treatment facility for mosquito control, the first consideration should be whether the problem could be reduced by physical modification without compromising the facility's function. Physical modifications must be designed or reviewed by an engineer to insure they meet applicable design requirements. Possible design modifications may include changes to the flow rate, scarifying the pond bottom where it is no longer infiltrating as originally designed or enhancing drainage by some other method. Eliminating low spots that collect small amounts of standing water and altering vegetation may also be options.
- Repairs to drainage facilities may include reshaping pond slopes to eliminate isolated pools of water and cleaning the pond to remove vegetation.
- Ponds may be stocked with mosquito-eating fish, copepods or other predators recommended by the Washington Department of Fish and Wildlife (i.e., mud minnow, stickleback, and perch). Tadpoles, dragonfly larvae, diving beetles, back swimmers and front swimmers also prey on mosquito larvae. For more information, contact WDFW's Aquaculture Coordinator, Andy Appleby at (360) 902-2663 or e-mail him at appleaea@dfw.wa.gov.
- Over-watering and poor irrigation practices are common producers of mosquitoes around the home, in parks, in irrigated fields and on golf courses. Report standing water to appropriate maintenance personnel.
- Irrigated lands are among the highest producers of mosquito breeding sites in Washington State. High numbers of mosquitoes can develop in standing water as a result of flood irrigation. The actions below can help eliminate mosquito breeding sites by using physical controls (Colorado, 2002; Pratt and Moore 1993).

  1) Minimize standing water in fields so that it does not lie fallow for more than four days by improving drainage channels and grading.
  2) Tail waters should not be allowed to accumulate for more than four days at the end of the field.
  3) Keep ditches clean of heavy vegetation to promote more rapid drainage.

4) Have ditches repaired to reduce seepage to the extent practicable (elevated water tables can produce unintended standing water in fields).

5) Minimize flood and rill irrigation practices to the extent practicable.

6) Avoid over-watering.

Note: *Wetlands and greenbelts should not be drained or removed.* Healthy wetlands provide minimal habitat for mosquitoes because water conditions, water quality, and natural predators deter mosquito use and minimize larval success if egg laying occurs. Predators, including other aquatic insects, amphibians, bats and birds, feed heavily on any mosquitoes present. Wetlands are a critical element in a healthy ecosystem that benefits people, water quality and wildlife. Wetlands cleanse and slowly release rainwater and provide flood protection and wildlife habitat. Many wetlands recharge groundwater critical for local drinking water supplies and prevent streams from drying up during the summer. We will not eliminate mosquitoes by draining wetlands and removing greenbelts. In fact, we could actually increase the mosquito population if their natural predators are destroyed because many mosquito species need only a small puddle or depression to breed.

2. Monitoring for high mosquito populations and disease

Risk Assessment: Probability of outbreak in humans: Remote to low
Action threshold: The presence of vector or nuisance mosquitoes suspected or confirmed in the area.
Rationale: Base-line data on mosquito populations from a variety of habitats will help target educational efforts and are essential to control efforts, should they become necessary.
DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction and public education emphasizing personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates high potential for human risk to increase.
Minimum BMP Response: Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic surveys (inventory habitats and map mosquito populations).

A. Monitoring for high mosquito populations and disease *around private homes or offices*:

- Accurately map and identify rearing areas for mosquitoes, by species if possible. These would be those sites for mosquito rearing that cannot be eliminated by following preventative measures such as container emptying, proper pond maintenance, and eliminating excess standing water by using appropriate irrigation BMPs. This is important because appropriate treatment measures are contingent on the habitat (species) encountered. The following Northwest mosquito habitats and control issues have been identified in the Mosquito-borne Response Plan developed by the Department of Health (Lilja, 2002):

Floodwater *Aedes vexans* and *Ochlerotatus sticticus*, which develop in large numbers along the borders of the Columbia and other rivers, create one of the most important mosquito problems in this region. The larvae hatch in the spring or early summer when the streams overflow areas such as willow and cottonwood swales where the eggs have been laid. The eggs of these species are dormant when temperatures remain below 45-50º F. Partial dormancy of the eggs may continue until sometime in June so that only some of the eggs are hatched by floods occurring in April or May. In some seasons, the larger rivers may rise, recede, and rise again to cover the same egg beds and produce an additional hatch. In other seasons, two or three successive rises may occur, each of which is higher than the last. Females that emerge in the first hatch may lay eggs that will hatch in the second or third rises of the river. Most of the eggs are laid between the 10 and 20 foot levels, and some of the eggs that are not flooded during a series of low flood crest years remain viable for as long as four years.

Large *Aedes vexans* and *Ochlerotatus sticticus* breeding areas have been managed efficiently in the past by controlling water levels above Bonneville Dam. Dikes have prevented flooding in other areas. Clearing of brush has been of value in some locations. However, control of the major section of these types of breeding areas must often be accomplished with insecticide applications.

Irrigation Water Breeding places for several mosquito species are provided by irrigation water. *Aedes dorsalis, A. vexans, Ochlerotatu melanimon*, and *Ochlerotatus nigromaculis* are among the most important species that may develop when water is applied and stands for a week or 10 days. Other species such as *Culex tarsalis, Culiseta inornata,* and *Anopheles freeborni* may be produced if water remains for longer periods. Tremendous numbers of mosquitoes breed in many areas where uncontrolled irrigation is practiced. Applications of insecticides are effective but are not substitutes for proper grading. Elimination of standing water is effective in preventing development of mosquitoes. Application of insecticides may be necessary for breeding places that cannot be drained.

Tidal Waters *Aedes dorsalis* is the only species that can breed in large numbers in both fresh and salt water in the Northwest. The larvae develop in some coastal areas where potholes are filled by the higher tides or where water levels fluctuate in permanent or semi-permanent pools. Leveling, drainage, or similar practices are effective in preventing breeding, but such areas must be properly maintained. Insecticide control may be necessary where these methods are inadequate or ineffective. *Ochlerotatus togoi* has also been found in coastal areas including San Juan, Island, Skagit, Kitsap, and Mason counties. Larvae of this species have been found in pools of pure seawater along rocky shorelines.

Snow Water In many high mountain meadows and also at lower levels mosquitoes breed in pools caused by snow melt. Development may require several weeks at higher elevations. *Aedes communis, A. cinereus, Ochlerotatus hexodontus, O. fitchii*, and O. *increpitus* are the most common species found in these locations. Usually there is only one generation per year, but the large numbers that may be produced are a severe annoyance to those who are working or seeking recreation in these areas. Elimination of breeding areas by drainage or maintenance of constant water levels is practical in some situations. Insecticide applications might have to be made by hand or by plane because of inaccessibility to heavy ground equipment.

Permanent Waters, Ponds and Artificial Containers The mosquitoes that lay their eggs on the water are usually found where water is present continuously during the season or at least for several days. Such locations include natural permanent ponds, including still waters along the borders of lakes and rivers sheltered from wave action and currents with some degree of vegetation, log ponds, tree holes, semi-permanent ponds and wetlands of various types, and artificial containers. *Culex tarsalis, C. pipiens, C. peus, Anopheles freeborni, A. punctipennis, Culiseta incidens,* and *C. inornata* are commonly found in such places. *C. tarsalis* and *C. pipiens* develop in large numbers in log ponds. *C. pipiens* also develops in large numbers in sewer drains, catch basins, and water left in artificial containers. *Coquillettidia perturbans* are found in permanent water in wetlands, swamps and marshes that have emergent or floating vegetation. Insecticides are often used effectively to control most of these species, except those breeding in artificial containers that can be emptied. Larvae of *C. perturbans* are difficult to control because they are attached to the roots of plants. Insecticide granules are sometimes applied, but eliminating host plants may be the most useful procedure to control this species.

Stormwater In response to the anticipated arrival of West Nile virus in King County, King County Water and Land Resources developed recommendations for dealing with the mosquito control at County drainage facilities. The study (Whitworth, 2002) identified the four basic habitats preferred by mosquitoes, the types of mosquitoes associated with the habitat type, and the WNV vector mosquito species that prefers each habitat type. Table 1 summarizes this information.

Table 1. Disease Vector Mosquito Species Associated With Drainage Control Facilities

Habitat Type	**Facility type**	**Vector Species**
Permanent Water	Year round wet ponds Larger Regional Ponds Wet Bioswales	Anopheles punctipennis
Marshes & Wetlands	Wet Bioswales Some Regional Facilities	Aedes cinereus Coquilletidia preturbans
Temporary or Flood Water	Temporary Wet Ponds Dry Bioswales Retention/Detention Ponds Open Ditches	Aedes vexans Culiseta inornata
Artificial Containers / Tree Holes	Catch Basins Underground Tanks/Vaults Discarded containers & Tires	Ochlerotatus japonicus Culex pipiens Culex tarsalis Culiseta inornata

- Once the mosquito habitats have been mapped, confirm mosquito species associated with habitats, if possible.

Resources: Techniques and equipment for adult mosquito surveys can be found at: The Centers for Disease Control and Prevention, Guidelines for Arbovirus Surveillance in the United States, 1993, Appendix II 51-54. These guidelines are also copied in Appendix B of the Department of Health's Mosquito-Borne Disease Response Plan, November 2002 Edition, available online at:. http://www.doh.wa.gov/ehp/ts/Zoo/WNV/WAArboviralRespPlan.pdf.

- Conduct larval surveys in the area of control by dipping. The following guidance on dipping is based on an article entitled "Seven ways to a successful dipping career," published in *Wing Beats*, vol. 6(4): 23-24 by O'Malley, 1995:

  Benefits of Larval Surveillance Larval surveys are used to determine the locations and seasons that mosquitoes use specific aquatic habitats and, when specimens are identified and counted, the information can be used to determine species composition and population densities. The information can be used to determine optimal times for application of larval control measures, including chemicals, biological controls, draining or impounding. It can also be used to help assess the effectiveness of both chemical and biological control measures. Routine larval surveillance data can be useful in interpreting adult mosquito surveillance data. For example, if larval surveys indicate 95-100 percent control by larvicides and yet the number of adults does not decline, one can suspect, in the absence of reinfestation, that an important larval concentration was missed. A system for the detection of insecticide resistance is also provided through a larval surveillance program.

Sampling Larvae Because mosquito larvae are found in a wide variety of habitats, a number of different sampling techniques to determine their presence and density have been developed. Many, if not all, of the published methods are described in Mike Service's book, *Mosquito Ecology Field Sampling Methods* (Elsevier Applied Science, 1993). Some methods are complex mechanical devices, but the most commonly used larval collection method is the "standard dipper," a plastic or metal, white or aluminum, solid or screen-bottomed pint-to-quart-sized scoop-on-a-handle, that, along with the "sweep net," defines the Ultimate Inspector.

Dipping for mosquito larvae begins after your area has been mapped for targeted habitats with proximities that pose risk to population areas of concern. Dipping locations in control areas with multiple mosquito habitats may need to be prioritized.

The species of mosquitoes one is looking for, and the type of habitat being sampled, will, in part, determine the sampling method used. Thus, it is important that field personnel know the preferred breeding habitats and seasonal occurrence of species known or suspected to be present within an area.

Eggs are white when first deposited, becoming dark within an hour or two (Pratt, 1993, p. 13). Eggs can be laid singly on the surface of the water, in clusters called rafts that float on the surface of the water, under the water attached to roots and stems of aquatic vegetation and singly on damp soil.

When searching for mosquito larvae, proceed slowly and carefully. Approach the area with caution to avoid disturbing larvae at the water's surface. Vibrations from heavy footsteps, casting a shadow or moving vegetation that contacts the water may be enough to cause larvae to dive to the bottom. Try to approach the water while facing the sun and with quiet, slow, soft steps. Gently move vegetation only as necessary.

Mosquito larvae of most genera, particularly the common *Culex, Aedes,* and *Anopheles*, are usually found at the water's surface and frequently next to vegetation or surface debris. In larger pools and ponds, they are usually near the margins, not in open, deep water. Dipping should be concentrated around floating debris and aquatic and emergent vegetation. If there is a strong wind, dipping should be done on the windward side of the habitat where larvae and pupae will be most heavily concentrated. Look for larvae and pupae before beginning to dip, if possible. If it is raining on the water's surface, wait until the rain stops.

Each water body may contain a number of different microhabitats which could contain different mosquito species. Microhabitats are places where a single species may congregate, as under tree roots, within clumps of emergent vegetation, under floating or overhanging vegetation and in open water. Learn to recognize different microhabitats within an area and sample as many as possible in order to obtain an accurate picture of the area's species composition.

Seven Ways to Dip There are seven basic ways to dip for mosquito larvae. Which one or ones you use depends on the genus or genera of mosquitoes you suspect may be present, and on the habitat, microhabitat and weather conditions. The following table lists vector mosquitoes in Washington State, their habitats, ranges and breeding sites. This table is meant to assist field identification efforts and dipping strategies. The seven dipping methods are described below the table.

Table 2. Disease carrying mosquitoes in Washington State					
Mosquito Species	**Day or Night Biter**	**Range**	**Generations per Year**	**Preferred Habitat**	**Breeding Comments**
Aedes cinereus	Aggressive during day	Does not travel far from habitat	One-eggs hatch at different times	A woodland species: semi-permanent bogs & swamps, wetlands, wet bioswales & floodwaters	Hatches in the early spring. Larvae found among dense aquatic vegitation.
Aedes vexans	Day & Night	20+ miles	Many	Any temporary water body like ditches, puddles, containers, pools & floodwater.	Eggs may lie domant 3+ yrs, hatches in ditches, still water.
Anopheles punctipennis	Night	Stays near habitat.	One	Springs and creeks connected to stormwater ponds, bioswales and wetlands.	Prefers algae-laden, cool pools on edges of slow flowing rivers and streams. Has entirely dark palpi.
Coquilletidia preturbans	Night - often comes to lights	Strong fliers, enters homes and lit areas.	One, but hatchlings do not complete development until the following spring.	Permanent marshes, wetlands, temporary wet ponds, dry bioswales & open ditches.	Needs thick growth of aquatic vegetation. Remains below the water surface attached to roots and stems. Hatchlings emerge in spring.
Culex pipiens	Night	Usually migrates only short distances.	Many	Found around water with high organic content, as in catch basins & sewer effuent ponds, tree holes, artificial containers & manholes.	Proliferate in in artificial containers. Lays eggs in clusters of 50 to 400. Larval and pupal stages take 8 -10 days.
Culex tarsalis	Night	Enters buildings after dark.	Many	Any fresh water, artificial containers, & agricultural and irrigated areas	Larvae develop from spring to fall in waters w/ high organic material. Eggs laid in rafts of 100 - 150 & hatch w/in 48 hrs.
Culiseta inornata	Dawn & Dusk	Stays near habitat.	Many	Cold water - associated with glacial runoff and sunlit waters, does not like hot weather. Found at all elevations.	Breeds throughout spring and summer in cold water, females may appear during warm winter breaks. Usually feeds on livestock, not people.
Ochlerotatus japonicus	Day & Night	Not known	Many	Artificial containers, catch basins, undergound tanks and vaults & tree holes	Larvae are found in artifical containers.

The *Seven Ways to Dip* are based on an article by Claudia O'Malley reprinted in the *Mosquito-Borne Disease Response Plan, November 2002 Edition*.

The first and usually the best method to start with is the SHALLOW SKIM. The shallow skim consists of submerging the leading edge of the dipper, tipped about 45 degrees, about an inch below the surface of the water and quickly, but gently, moving the dipper along a straight line in open water or in water with small floating debris. End the stroke just before the dipper is filled to prevent overflowing. The shallow skim is particularly effective for *Anopheles* larvae that tend to remain at the surface longer than *Aedes* and *Culex*. *Anopheles* are usually associated with floating vegetation and debris.

The second method to try in open water, with or without floating objects, is the COMPLETE SUBMERSION. Many mosquito larvae, particularly those of the genera *Aedes* and *Psorophora*, are very active and usually dive below the surface quickly if disturbed. In this case, a quick plunge of the dipper below the surface of the water is required, bringing the dipper back up through the diving larvae. Bring the dipper up carefully to avoid losing the larvae in the overflow current.

When you need to sample at the edges of emergent vegetation, try the PARTIAL SUBMERSION technique. To do this, push the dipper, tilted at about 45 degrees, straight down adjacent to the vegetation. This causes the water around the vegetation to flow into the dipper, carrying the larvae with the flow. There is no need to move the dipper horizontally. Pull the dipper up before it is full.

In very shallow water, try the FLOW-IN method. Larvae can be collected by pushing the dipper into the substrate of the pool and letting the shallow surface water, debris and larvae flow into the dipper. Do not move the dipper horizontally.

To sample for larvae that may be under floating or emergent vegetation, use the SCRAPING technique. This method is used in habitats that contain clumps of vegetation such as tussocks of sedges, floating mats of cattails, water lettuce, or other plants that are too large to get in the dipper, or clumps of submerged vegetation such as hydrilla or bladderwort. Dip from the water in towards the vegetation and end by using the dipper to scrape up against the base or underside of the vegetation to dislodge larvae. This method is usually more effective if the bottom of the dipper is screened and it is often used to sample for *Coquillettidia* and *Mansonia* mosquitoes.

The SIMPLE SCOOP is the “dipping to get water” method that was discouraged earlier. It consists of simply scooping a dipperful of water. This is probably the most commonly used method, particularly by new inspectors, and it is often the method referred to in much of the literature as “the standard dipping procedure.” While it can be successfully used to collect *Culex* larvae, it is still not the method of choice.

The dipper can also be used as BACKGROUND. This is especially useful in woodland pools and other shallow water or when larvae are disturbed and dive to the bottom. Submerge the dipper completely to the bottom litter and slowly move it around. The darker mosquito larvae and pupae will stand out against the background of a white or aluminum dipper. Once larvae appear in the dipper, just lift it upward.

One or more of these methods, properly used, can determine the mosquito species composition of most aquatic habitats, excluding those whose openings are smaller than the dipper, such as tires, rock pools, tree holes and tree root systems like those found in cedar and red maple swamps. In those cases, a smaller container, such as a vial, measuring spoon or tea strainer can be used in the same seven ways as the dipper described above. Then there is the tubular dipper, or chef’s poultry baster, for those really hard to get to places such as plant axils, tree holes and tree root holes.

Note: Locations and times of dips, and well as larvae counts, need to be recorded.

B. Monitoring for high mosquito populations and disease in *wide areas* includes the mapping and surveying strategies used for homes and offices described above, plus:

- Conduct ongoing surveillance, including studying habitats by air, aerial photographs and topographic maps, and evaluating larval populations.
- Monitor and track data from mosquito traps, biting counts, complaints, and reports from the public.
- Keep seasonal records in concurrence with weather data to predict mosquito larval occurrence and adult flights.
- Consider conducting surveillance for diseases carried by mosquitoes and harbored by birds, including crows and sentinel chicken flocks.
- Accurately map and identify rearing areas for mosquitoes. These would be those sites that cannot be eliminated by preventative measures such as emptying containers, proper pond maintenance, and eliminating excess standing water by using appropriate irrigation BMPs. These habitats can be identified by aerial photo assessments, topographic maps, and satellite imagery where available. This is important because appropriate treatment measures are contingent on the particular species that live in specific habitats.
- Agricultural site maps should include the following: Hay, pasture, circle irrigation, orchards, and rill irrigated field crops. An important land use that has caused problems to mosquito control districts in the past is flood irrigated pastures where the water stays on more than five to seven days. These areas should be mapped so that appropriate management responses may be taken.
- Demarcate on maps no-spray zones. This may include areas such as schools, hospitals, fish farms, and the homes of individuals who are on chemically sensitive registers and crops grown under a certified organic program. Other crop sites that do not have a tolerance for the mosquito control products used should also be listed. If the control entity is not a mosquito control district organized under RCW 17.28, then individual residences, where the occupants do not want to be treated, should be identified as no-spray zones.

Note: Detailed information on mosquito surveillance is available in Washington State Department of Health's publication *Mosquito-borne Disease Response Plan,* November 2002 ed., available online at http://www.doh.wa.gov/ehp/ts/Zoo/WNV/WAArboviralRespPlan.pdf . Training on surveillance, trapping techniques, sampling, and vector identification techniques has been offered by Major William Sames, Chief Entomological Science Division of the U.S. Army, CHPPM-West, Fort Lewis WA. His e-mail address is william.sames@nw.amedd.army.mil and his telephone number is (253)966-0008.

3. Establish the targeted density of mosquito populations based on health, public safety, economic and aesthetic thresholds

Risk Assessment: Probability of outbreak in humans: Remote to low
Action threshold: The presence (positive identification) of any vector mosquitoes in the area may trigger activities to reduce their presence. Since people with compromised immune systems are likely to be the most vulnerable to mosquito-borne diseases, areas of their exposure should be a priority. General Permit Condition S4.2.C infers that the targeted density of larvae is < 1. The permit states: Pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip, and the need to apply insecticides to control mosquito populations.
Rationale: Once vector mosquitoes have been positively identified in an area, control treatments are warranted. If the cost of treatments is prohibitive, every effort should be made to educate those at risk of exposure about minimizing habitat and personal protection measures.

DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction, and public education emphasizing personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates likely potential for human risk to increase.
Minimum BMP Response: Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic survey (inventory habitats and map mosquito populations). Using surveillance information and input from the people in the control area, establish the targeted density of mosquito populations based on health, public safety and funding.

A. Establishing the targeted density of mosquito populations based on health, public safety, economic and aesthetic thresholds around private homes or offices:

- Individual homeowners and businesses must determine the targeted density of mosquito populations in their area, absent the existence of a mosquito control district. This determination should be based on factors of risk and cost.

- Once the targeted density has been established, continue larvae surveys to find density response to habitat minimization efforts and need for larvicide treatments.

B. Establishing the targeted density of mosquito populations based on health, public safety, economic and aesthetic thresholds for wide areas:

- Mosquito control agents must consult with their sponsors to determine targeted mosquito densities. This determination should be based on factors of risk and cost.

- Once the targeted density has been established, continue larvae surveys to find density response to habitat minimization efforts and to assess the need for larvicide treatments.

4. Treat mosquitoes to reduce populations below the targeted threshold using strategies that may include biological, cultural, mechanical, and chemical control methods and that must consider human health, ecological impact, feasibility, and cost effectiveness.

Risk Assessment: Probability of outbreak in humans: Low to moderate
Action threshold: The positive identification of any vector mosquitoes in the area may trigger activities to reduce their presence. Once minimization strategies have been taken, larvae surveys (*i.e.* dipping) can indicate the effectiveness of those efforts and the need for further action. General Permit Condition S4.2.C infers that the targeted density of larvae is <1 to commence larviciding. The permit states: "Pesticide applications shall not commence unless surveillance of a potential application site indicates a larva/pupa count of greater than 0.3 per dip and the need to apply insecticides to control mosquito populations." This level is a minimum; mosquito control agents may want to set the targeted density at a higher level due to cost and risk factors.
Rationale: Once vector mosquitoes have been positively identified in an area, control treatments are warranted. If the cost of treatments is prohibitive, every effort should be made to educate those at risk of exposure about minimizing habitat and personal protection measures.
DOH Recommended Response: Obtain surveillance and control resources to enable emergency response. Increase larval control and source reduction, and educate the public about personal protection measures, particularly among the elderly. Enhance human surveillance and activities to further quantify epizootic

activity, such as mosquito trapping and testing. Consider targeted adult mosquito control if surveillance indicates likely potential for human risk to increase.
Minimum BMP Response: Conduct outreach and education; monitor and track avian mortality, human encephalitis/meningitis, and equine surveillance in the area of control. Conduct entomologic survey (inventory habitats and map mosquito populations). Using surveillance information and input from the people and/or sponsors of control in the control area, establish the targeted density of mosquito populations based on health, public safety and funding. If the targeted density level for larvae is measured after all habitat minimization efforts have been taken, prepare for targeted larvicide treatments. Prepare for an emergency response if warranted by human health impacts.

A. Use an IPM approach around private homes or offices *and* in wide areas of control:

- Select treatments using the most effective control method or combination of methods for the particular species of mosquitoes and the breeding area found by larvae surveys.
- After attempts to minimize breeding sites have been exhausted and personal protection information has been dispersed, use biological measures whenever feasible and efficient.
- **Biological methods** may include stocking species such as the Three-Spined Stickleback (*Gasterosterous aculeatus*) in ponds or impoundments. The Three-Spined Stickleback is native to Washington State and known to be an effective predator of mosquitoes. Guppies, goldfish and other fish commonly sold in pet stores are exempt from permitting by Washington's Department of Fish and Wildlife (WDFW) and may be suitable for smaller ponds, horse troughs and ornamental pools. However, before planting any of these exempt fish, please consult with WDFW. Some of these fish, such as goldfish may have severe ecological impacts on ponds and lakes.

  The Mosquito Fish (*Gambusia affinis*) has been used for mosquito control in virtually every state because of the adult's ability to consume large amounts of mosquito larvae. These warmwater fish rarely exceed 2.5 inches and prefer shallow water. They tend to flourish in almost any environment, including well discharges, cisterns, water tanks, potholes, rain barrels and open septic tanks. *Gambusia* have been known to dramatically reduce and even eliminate mosquito larvae. WDFW suggests that the use of *Gambusia* be integrated into an overall mosquito control plan rather than used as an exclusive solution to mosquito abatement. Permits must be obtained from WDFWWFDW for use of this non-native species as a mosquito control measure.

  WDFW has several concerns with stocking biological mosquito predators in Washington waters. Along with the introduction of non-native fish, the transfer of fish diseases from one location to another, even among native populations, can cause disease outbreaks. That is why all movement and stocking of fish requires a permit from WDFW, whether the fish are native or not. Due to the inability to test live fish without killing them, the transportation of fish from one watershed to another requires disease testing (usually on the adults at spawning, or by sacrificing a number of young fish), and verification that the remaining fish are reared on disease-free water. In addition, any non-native fish stocking currently needs to go through SEPA review prior to approval. The laws in Washington State are designed specifically to prevent this type of "Johnny Apple-seeding" from occurring. For more information, please contact WDFW's Aquaculture Coordinator, Andy Appleby at (360) 902-2663 or e-mail appleaea@dfw.wa.gov.

TABLE 3. PERMITTED INSECTICIDES USED FOR MOSQUITO CONTROL

Typical Products	Active ingredient	Label use rate and 2002 cost	Application method(s) persistence and comments	Human Health Impacts	Environmental Impacts	Target Pests on label
Aquabac, Bactimos, Vectobac and Teknar	(Bti) *Bacillus thuringiensis israelensis*	0.25 to 2 pints/acre or up to 10 lbs/acre Granules $1.45/lbs	Hand sprayer, ground sprayer or sprinkler cans. Effective 1 - 30 days depending on formulation. Broad spectrum, except *Coquilletidia*	Not for potable water. Minimal non-dietary and dermal risk to infants and children.[1]	Non-toxic to most non-target species, moderately toxic to *Daphnia*[2]	Mosquito larvae
VectoLexWDG	*Bacillus sphaericus* (H-5a5b)	0.5 to 1.5 lbs/acre $4.65/lb	Granules are mixed with water and sprayed. Effective for 1-4 weeks, depending on the species of mosquito larvae, weather, water quality and exact form of the granules. Effective on *Culex spp*. Less effective against other species.	Not for potable water. Essentially nontoxic to humans[3]	No risks to wildlife, nontarget species or the environment[3]	Larvae control in water with high organic content.
Altosid liquid	Methoprene: Active ingredient is a growth hormone that does not allow the mosquito larvae to mature. Effective in controlling most mosquito species in WA	2 to 20 lbs/acre $236/gal	Use hand and ground sprayers. Effective for a few days unless specially formulated for slow release. It is not persistent because it degrades rapidly in water. The briquettes are used in areas needed for longer term residual control such as ponded areas of standing water, areas where flood waters may make it impossible to use Bti. Rates increase with deeper water. Altosid XR-G is a sand formulation, good for pastures or marshes with thick vegetation.	Not for potable water. Does not pose unreasonable risks to human health[3]	Moderately toxic to warm-water, freshwater fish, slightly toxic to cold-water, freshwater fish. **Highly acutely toxic to most invertebrates**.[4]	Horn fly, mosquito larvae, cigarette beetle, tobacco moth, sciarid fly, flea larvae, mealy bug and spider mite.
Altosid pellets	Methoprene	2.5-10 lbs/acre $28.75/lb				
Altosid XR	Methoprene	1 briquette 100-200 sq ft. $2.80 @				
Altosid briquette	Methoprene	1 briquette / 100 sq ft. $.93 @				
Altosid XR-G	Methoprene	8-10 lbs/ac $8.43/lb				

Typical Products	**Active ingredient**	**Label use rate and 2002 cost**	**Application method(s) persistence and comments**	**Human Health Impacts**	**Environmental Impacts**	**Target Pests on label**
Agnique MMF	Monomolecular surface film *Poly(oxy-1,2-ethanediyl)Alpha-isooctadecyl-hydroxy*	0.2 to 0.5 gal/acre @ $200/gal.	Sprayed by hand or ground equipment. Film remains active for 10-14 days on floodwaters, brackish waters and ponds. It is susceptible to wind breaking the surface tension and could be rendered ineffective at winds above 10 mph and in very choppy water. Adult females are killed by entrapping and drowning when they contact the surface to lay their eggs.	Okay for potable water, livestock, backyard ponds, pool covers. No risk to human health[3]	Less environmental impact than oil-kills pupa stage. Films pose minimal risks to the environment[3] Arthropods may be harmed	Larvae, pupae and midge control. Adult females.
Golden Bear Oil Bonide Oil	Petroleum distillate oils prevent the larvae from obtaining oxygen through the surface film	3 to 5 gal/acre $11/gal	Liquid formulations are sprayed by hand or ground equipment. Persists for 12 – 15 hours, then evaporates. Less expense--kills pupae stages	No risk to human health.[3]	Misapplied oils may be toxic to fish and other aquatic organisms. Label precautions reduce such risks.[3]	Larvae and pupae control
Abate **Emergency use only!**	Temephos	0.5 to 1.5 oz/acre $2.00/oz	Sprayed liquid. Breaks down within a few days in standing water, shallow ponds, swamps, marshes, and intertidal zones. Temephos is applied most commonly by helicopter but can be applied by backpack sprayers, fixed-wing aircraft, and right-of-way sprayers in either liquid or granular form. **Product of last resort.**	Not for potable water. Poses low risk to human health. High dosages, like other OPs*, can over-stimulate the nervous system, causing nausea, dizziness, and confusion. [3]	Poses severe risk to nontarget aquatic species and the aquatic ecosystem. Very highly toxic to some aquatic invertebrates. Moderately toxic to very highly toxic to trout. 6	Mosquito larvae, midge, punkie gnat, and sandfly larvae in non-potable water.

*OPs are organophophates

1. http://www.epa.gov/oppbppd1/biopesticides/factsheets/fs006476t.htm p. 3
2. http://www.epa.gov/oppbppd1/biopesticides/factsheets/fs006476t.htm p. 5
3. http://www.epa.gov/pesticides/citizens/larvicides4mosquitos.htm#microbial
4. http://www.epa.gov/oppsrrd1/REDs/factsheets/0030fact.pdf pp.4-5
5. http://www.epa.gov/pesticides/citizens/malathion4mosquitos.htm p. 2
6. http://www.epa.gov/oppsrrd1/REDs/factsheets/temephosfactsheet.pdf pp. 22-23
7. http://www.epa.gov/oppsrrd1/op/malathion/summary.htm

Acquire Appropriate Management Assets

- Select appropriate mosquito management personnel: If personnel are hired directly by the public mosquito control entity, the following experiences shared by mosquito control districts should be considered:
- Turnover can be high due to temporary nature of job, and frequent re-licensing may be needed. (All mosquito treatment personnel are required to pass the public health control exam.)
- Some pay a fairly high salary to acquire mature workers who return every year.
- Where a lower salary is paid, incentive programs for second year returnees (mostly college students and teachers) have been successful in getting employees to return.

Select Application Equipment Appropriate for site size, habitats treated, and budget constraints:

- Small Size Sites- Puddle size to 10 acres: Primarily the hand method (Cyclone Spreader) application technique. Costs can vary but one eastern Washington district is able to cover 51 sites in a 23 mile stream flood plain for a total cost of $8000 per year.
- Moderate Size Sites -10 square feet to 250 acres: Primarily Truck Based Application Technique: Costs can vary from about $13 per acre and up. Some districts have variable rate tax structures such as 10 cents/ $1000 valuation for sagebrush areas, 20 cents/ $1000 valuation for wetland areas, and 30 cents/ $1000 valuation for residential areas. The total annual budget for some of the larger operations could be a million dollars or more.

Large Size Sites-10 square feet to 250 acres: 2,500 to 10,000 acres- Primarily Aerial based Application Technique: Costs can vary from about $0.32 per acre and higher. While this is the most cost effective way to treat large acreages, the initial outlay requires an aircraft equipped for spray application. The total annual budget for a large scale operation could be a million dollars or more

Contracted Personnel and Equipment (Commercial applicators): Contracted personnel can be used for all sizes of sites. However commercial applicators have been hired mostly for large site aerial applications. Costs can vary from one applicator to another and particularly with time of year and even time of day. Most commercial applicators have not had much experience in mosquito IPM management techniques. While they may be competent in applying a product at a particular rate, they do not always understand the behavior patterns and life cycles of the different species of mosquitoes. This ignorance can greatly degrade the effectiveness of the treatment. Therefore, the public health entity should verify that the applicators they hire have appropriate IPM training and experience in mosquito management, an appropriate public health category on their license, a positive attitude towards following the hiring entity's IPM program, and an awareness of the environmental issues surrounding mosquito abatement and their need to follow FIFRA labels and NPDES permit regulations. The hiring entity should also be aware that if their contractor violates Federal regulations, such as CWA, or ESA, the hiring entity may also be found liable under a third party lawsuit (as was the case in recent court case in New York over a contracted mosquito abatement program organized to combat the West Nile Virus).

B. What constitutes an emergency: when to consider adulticides and how adulticides fit into an IPM plan

An emergency may arise when communities have not prepared for mosquito control and an outbreak occurs. In such cases, the responsible officials should immediately initiate an education and outreach program that emphasizes habitat minimization and personal protection, begin conducting larvae surveys, and secure the funding, permits and licenses needed for applying insecticides. Since insecticides can be aerially applied, the use of fogging equipment would only be needed in extremely rare cases where access is limited.

The use of any pesticide in water needs to be permitted under the Clean Water Act to protect the applicator from enforcement liability. In the case of an emergency, the use of temephos may be authorized. Temephos is an organophosphate that is conditionally allowed for mosquito control in surface waters of the state only when one of the following two conditions is met:

- As a result of consultation between the departments of Health and Ecology, in response to the development of a human health emergency as determined by the Washington State Department of Health.
- As a result of consultation between the departments of Agriculture and Ecology, and then only in response to the development of pesticide resistance within a population of mosquitoes. Monitoring of insecticide persistence and residuals shall be a condition of such approval.

Select triggers for the use of adulticide products: Adulticiding of residential areas and upland areas where mosquitoes are migrating should be considered only when there is evidence of mosquito-borne epizootic activity at a level suggesting high risk of human infection. The following are examples of this type of evidence: high dead bird densities, high mosquito infection rates, multiple positive mosquito species including bridge vectors, horse or mammal cases indicating escalating epizootic transmission, including bridge vectors, horse or mammal cases, or a human case with evidence of epizootic activity.

Follow legal restrictions on the use of adulticide products (based on FIFRA and ESA regulations): Even when the above evidence is present, direct *application to streams is prohibited* by all adulticide labels (FIFRA) due to harm these products can do to aquatic species. Special care needs to be taken near ESA listed streams which could result in "harm" or "take" violations being assessed against the public entity if the product is sprayed into the water. The Department of Ecology, under Clean Water Act authority, prohibits the use of adulticide products on such habitats. It also prohibits such products from being directly applied to storm drains.

BMPs for adulticides:

1) Meteorological conditions:
    - Check wind speed and direction before spraying and be observant of all changes in direction and speed during the application. Use appropriate wind indicators. Gauges are highly recommended for ground applications, and smoke for aerial applications.
    - Check temperature at different elevations to decide if there is an inversion.
    - Spray only when wind is away from sensitive sites.
    - Dusk is the recommended time to spray when mosquitoes are out.
2) Minimum wind conditions and temperature inversions:
    - Air inversions can go from 50 to 600'.
    - Inversions can be used to force the droplets down.
    - Spray under the inversion and only when conditions will not allow the cloud to drift into the stream.
3) Maximum Wind: Do not spray in winds over 10 mph.
4) Fish-bearing stream spray buffers: Establish buffers that are outside the maximum equipment spray swath with a minimum distance of 50-150' (depending on the skill of the operator) or follow label buffer if it is greater.
5) The following is a table that outlines the mosquito adulticides that may be used in terrestrial applications in Washington State.

Table 5. Adulticides which may be used in Washington.

Typical Products	Active Ingredient	Label Use Rate	Use	Cost	Residual Life	Comments
Biomist & Kontrol	Permethrin	ULV 4 oz/acre	Adult Control	$.24/oz	24 hours	Effective, can't use close to water.
MGK 5%	Pyrethrin	ULV 1-4 oz/acre	Adult Control	$1.20/oz	1 hour	Natural pyrerthrin-expensive.
Scourge	SBP1382	ULV 4 oz/acre	Adult Control	$.58/oz	1-4 hours	Has not performed well in this area.
Cythion ULV	Malathion	ULV rates vary	Adult Control	$.24/oz	24 hours	Product of last resort.
Anvil	Sumithrin		Adult Control	$.40/oz	1-4 hours	Not tested in this area. No water precautions.

Note: Organophosphate ULV Products such as Fyfanon Ulv-(AI: malathion) are formulated for ultra low volume applications that are highly susceptible to drift due to extremely small particle sizes.

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